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APPARATUS FOR CONTINUOUS SOLIDS-LIQUID SEPARATION

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FOREWORD

The apparatus described in this paper was developed in the Environmental Systems Branch under task No. 793001, between January and May 1967. Patent disclosure was filed on 1[illegible] July 1967. This paper was submitted for publication on 5 December 1967.

H. B. Bartholomew of the Technical Services Branch assisted in the design and construction of the apparatus.

This report has been reviewed and is approved.

GEORGE E. SCHAFER
Colonel, USAF, MC
Commander

A..STRACT

An apparatus has been developed which allows high filtration with a Millipore filter on a continuous basis. The apparatus consists of a Plexiglas box built around a Millipore filter holder. The entrance port in the box contains a nozzle which increases the velocity of the incoming solution and directs it into a tangential flow pattern, thus simultaneously supplying the mixture to be filtered as well as washing the filter clean of separated solids. Filtrate containing only particles smaller than 0.45 μ in diameter can be recovered continuously at a rate of 100 ml. per hour.

APPARATUS FOR CONTINUOUS SOLIDS-LIQUID SEPARATION

I. INTRODUCTION

The continuous separation of solids from liquids, with recovery of both fluid and dewatered solids, is a problem that frequently arises in chemical and biologic processes. When encountered as a unit process on a large scale, the separation can be performed by many commercial units and technics (1) designed to effectively separate volumes greater than 60 liters/hour (at correspondingly substantial capital investments). In small pilot-plant or bench-scale studies, however, where volumes may only be a few liters a day, the problem of effective separation becomes acute.

There are many "batch" operations for separating small quantities of solid-liquid slurries or mixtures (such as centrifugation, gravity filtration, and vacuum filtration). However, no continuous separating system is currently available on the market which can be readily integrated into an existing process and allow further processing of the resulting liquid and dewatered solids.

A small-scale continuous separation system was needed in this laboratory for use on a high-solids activated sludge unit. Activated sludge is one of several candidate processes for degrading human wastes into non-noxious compounds which may be used to support plant life in a bioregenerative life-support system. In preliminary studies with our high-solids sludge unit, separation of the effluent from the biomass by ordinary flocculation and gravity sedimentation proved unsatisfactory because the biomass concentrations in these cultures were about ten times as great as conventional levels. A separator was desired which would remove the effluent from the sludge and return the dewatered solids to the culture vessel immediately in order to have a closed ecosystem.

A review of the literature revealed no apparatus which met our specifications—namely, one that was compact, inexpensive, had no moving parts, and could be easily serviced. The Millipore Filter Corporation has described a novel application of the Millipore filter (thin cellulose porous membranes using vacuum as the driving force to attain solids retention down to 0.45 μ in size) (2). This was the use of a Microweb filter (large flexible sheets of Millipore filter material) supported by mesh on a spinning drum. When the drum is evacuated, clarified effluent is drawn through the filter and the filter is kept clean by the high centrifugal force applied to the collected material on the spinning drum (3). While this system appears capable of long-term operation with continuous solids separation, the rotational characteristics (with its associated vacuum-sealing problems) appeared undesirable. Hence, the apparatus described below was developed to accomplish the same purpose but in such a way as to make a compact, inexpensive unit without the problems of rotary vacuum seals.

II. DESCRIPTION

Figure 1 presents a drawing of the apparatus with the component parts identified. It is constructed of Plexiglas, 1.3 cm. thick, built around a standard Millipore filter holder in the form of a box 8.9 by 12.7 by 9.2 cm. The box has stainless steel entrance and exit ports both having a diameter of 1.3 cm. The entrance port has a nozzle (measuring 2.54 by 0.16 cm.) which increases the velocity of the incoming solution and directs it into a tangential flow pattern, thus simultaneously supplying the new mixture to be filtered as well as washing the filter clean of any separated material clogged on its surface as a result of the vacuum filtration process. The Millipore filter paper is held in position by a circular stainless-steel ring, which distributes the pressure from three spring-loaded shafts connected to the top of the box, and by the vacuum from below in the vacuum suction flask. The top is held in place by ten screws and an "O" ring for an airtight fit. The top is removable for easy cleaning and filter service.

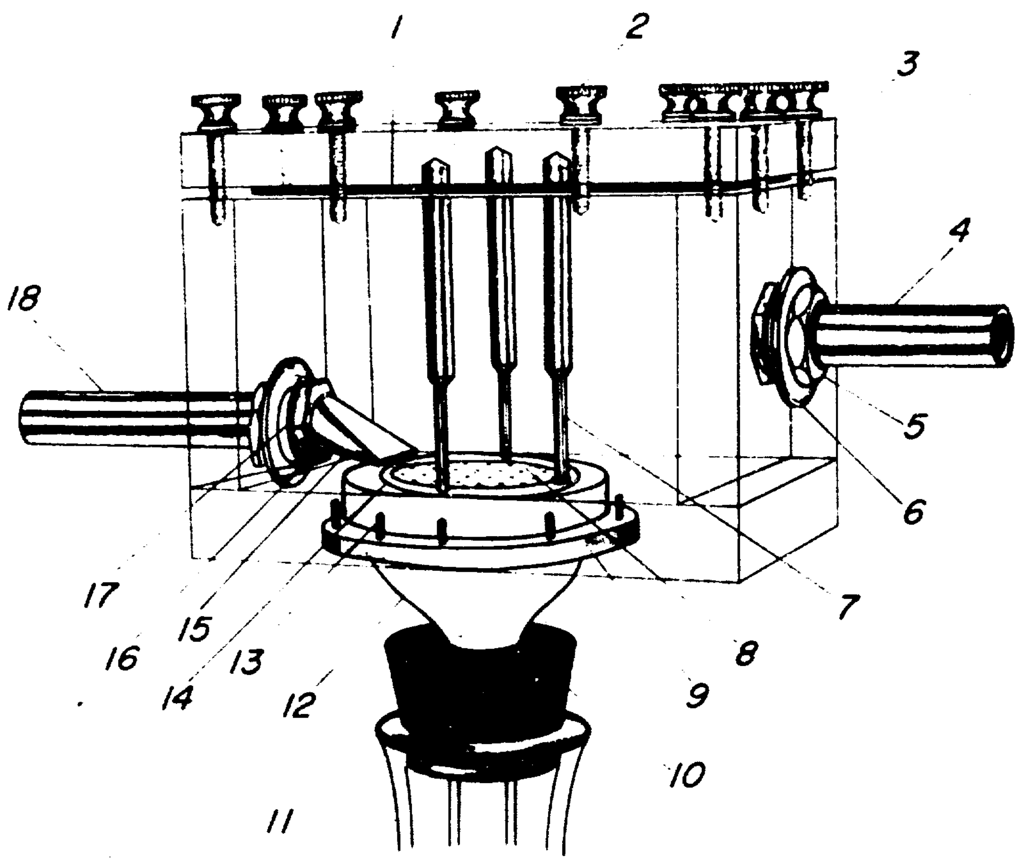

FIGURE 1

Continuous solids-liquid separation apparatus: (1) "O" ring seal for the removable top. (2) One of 10 screws which hold top on the Plexiglas box. (3) Removable top. (4) Outlet port. (5) Nut to hold outlet port flush with side of apparatus. (6) Flange to distribute pressure from holding nut. (7) One of 3 spring-loaded shafts which hold filter in place. (8) Millipore filter, type HA (0.45 μ, 47 mm.). (9) Fitting which keeps Millipore filter holder attached to the Plexiglas box. (10) Rubber stopper. (11) Vacuum suction flask. (12) Millipore filter holder. (13) Screws which attach fitting to Plexiglas box. (14) Stainless steel ring which distributes pressure from the 3 spring-loaded shafts to the filter paper. (15) Flow nozzle. (16) Nut to hold inlet port flush with side of apparatus. (17) "O" ring. (18) Entrance port.

The separation device is used as shown schematically in figure 2. The apparatus is placed on a vacuum suction flask and the pressure is lowered to 5 mm. Hg or less. This seats the filter properly and supplies the driving force for the vacuum filtration. The solution to be filtered is then pumped from its reservoir through the entrance port at a rate of 4 liters per minute. This circulation flow through the entrance nozzle is what causes the continuous washing effect on the filter. The dewatered solution leaves through the exit port and returns to the reservoir for another pass through the apparatus to be further dewatered.

III. DISCUSSION

The results of tests of the apparatus showed that when it was connected to the activated sludge unit under study, an effluent was obtained which contained no particles having a diameter greater than 0.45 μ in accordance with residue determinations in *Standard Methods for the Examination of Water and Wastewater* (4). It was found that filtration rates were between 100 and 150 ml. per hour (depending on the viscosity of the solution and the age of the filter) with a pressure of 5 mm. Hg or less in the suction flask and a circulation rate of 4 liters per minute of fluid through the nozzle. Table I compares the apparatus described in this paper with the conventional "batch" Millipore filter in terms of volumes of effluent recovered from our activated sludge unit per unit of time. It was found that the type HA (0.45 μ, 47 mm.) Millipore filter could be used to filter as much as 5 liters of effluent through the apparatus before it had to be changed. Changing was required not because of clogging but because the filter paper would start to wear as a result of the continuous high-speed flow of the fluid across its surface.

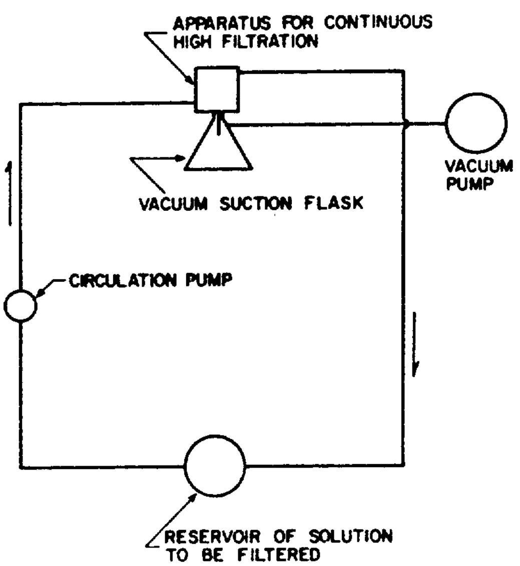

FIGURE 2

Arrangement used for separation process.

IV. APPLICATIONS

The most obvious application for the apparatus is its use in bacteriologic and microbiologic research and pilot-plant studies for removing spent media from cultures on a continuous basis with high filtration efficiency. Many other potential applications also exist in chemical processing studies for clarifying liquids or dewatering solids. The units can be considered "modular" and several units can be connected in parallel if larger volumes per unit of time are required.

TABLE I

Comparison of new apparatus with conventional Millipore

Time (min.)	Volume of effluent recovered at end of time period—	
	With conventional "batch" Millipore (ml.)	With new continuous Millipore (ml.)
0	0	0
0.5	0.9	0.7
1.0	1.8	1.5
2.0	3.4	3.1
4.0	3.6	6.2
8.0	4.4	11.6
16.0	5.2	24.9
32.0	5.4	52.0
64.0	5.5	103.0

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